# 1

# INTRODUCTION

This report, sponsored by the Federal Emergency Management Agency (FEMA), reviews the literature and existing procedures on rapid visual screening in order to determine a recommended procedure as a first step toward the development of a handbook on the rapid visual screening of buildings for potential seismic hazards. The intent of the Handbook, which will be referred to as the *ATC-21 Handbook* (ATC, 1988), is to provide the target audience with a standard rapid visual screening procedure to identify those buildings that might pose potentially serious risk of loss and life and injury, or of severe curtailment of community services, in case of a damaging earthquake.

A rapid visual screening procedure (Rapid Screening Procedure, abbreviated RSP) is a methodology that, with associated background information, would permit an individual to visually inspect a building and, by obtaining selected data, to arrive at a decision as to which buildings should be further studied by an experienced professional engineer who would conduct a more in-depth review of the seismic capacity using structural drawings, design calculations, and perhaps inspecting the structure itself. The RSP inspection and decision-making process typically would occur on the spot, with perhaps two to four "average" buildings being reviewed per person-hour (i.e., 15 to 30 person-minutes per building). The personnel doing the rapid screening would typically not be experts in earthquake performance of buildings, but rather building inspectors, technicians or junior engineers.

Visual inspection would be a "sidewalk survey" done from the street, without benefit of entry to the building and without access to the structural drawings or most other supplementary information. In some cases, general structural general structural system-related information may be available to the inspector via building department or tax assessor files. (Note, however, that experience has shown the latter often to be unreliable with regard to structure information.) In effect, the inspector would note the dimensions of the building, its occupancy, structural materials and systems, condition, and other information. This information would be entered onto a form (on a clipboard or electronically), and employed in algorithms to determine a seismic hazard ranking for that building.

The RSP would be the first step of a two or more step process, in which ideally the RSP would permit (i) identification of those buildings that require additional, more detailed investigation by qualified engineers, and (ii) prioritization of the buildings to be further investigated, so that technical and other resources could be most effectively utilized.

It should be emphasized that any RSP is by definition a very approximate procedure, which will almost certainly fail to identify some potentially seismically hazardous buildings. The goal is to broadly identify *most* of the potentially seismically hazardous buildings, at a relatively modest expenditure of time and effort, and to eliminate *most* of the relatively adequate buildings from further review. Lastly, an RSP is a methodology intended for rapidly evaluating the hundreds or thousands of buildings in a community. It is *definitely not* intended for the full determination of the seismic safety of individual buildings.

The target audience for the *ATC-21 Handbook* includes:

- local building officials
- professional engineers

- registered architects
- building owners
- emergency managers
- interested citizens

Any or all of these people might be involved in efforts to identify a community's seismically hazardous buildings and mitigate the hazard. It is recognized, however, that building inspectors are the most likely group to implement an RSP, and this group is considered the primary target audience.

This report identifies, reviews, and critiques those RSP's currently or previously used to evaluate seismically hazardous buildings. For each method the following is provided:

- a description and discussion of technical advantages and disadvantages, including suitability of scope and format, and costs of implementation

- impacts and implications of regional variations in construction practices and seismic loading levels

- suitability for use by each segment of the target audience

- the general level of uncertainty inherent in its use

Three main sources for identifying existing procedures were used:

- the technical literature

- discussions with jurisdictions and communities that have performed or attempted a survey of their seismically hazardous buildings

- practicing professional engineers who are called upon to provide opinions as to the seismic hazard of a building or other structures. (Prominent engineering firms have performed rapid screenings of hundreds of buildings.)

Technical literature was identified by electronic data retrieval (i.e., the Engineering Index, accessed via Dialog); citations furnished by the ATC-21 Project Engineering Panel; review of the National Information Service for Earthquake Engineering (NISEE) holdings at the Earthquake Engineering Research Center in Richmond, California; and information and references in the author's files.

There exists an extensive body of literature on methods of seismic analysis and/or review of existing buildings. However, most of these methods are simplified or more or less detailed engineering analysis procedures, involving computations of seismic demand and capacity, often with the benefit of the structural plans or similar detailed privy information. Although some of these methods contain an initial rapid visual screening element, most do not. Therefore, only those methods that explicitly have a rapid visual screening element have been reviewed herein, and no attempt has been made to review the much larger literature of seismic evaluation of existing buildings.

Following this first section, the remainder of this report consists of the following chapters:

Chapter 2:  Definition of an ideal rapid visual screening procedure, against which existing methods are judged

Chapter 3:  Summary of each of the RSP's identified

Chapter 4:  Presentation of the evaluation criteria used in this project and a detailed evaluation of the following aspects of the RSPs reviewed herein:

- Organizational
- Structural
- Configuration
- Site and Non-structural
- Personnel

Chapter 5:  Recommended procedure for rapid visual screening of buildings for potential seismic hazards

Lastly, the appendices include typical data sheets employed in several of the surveys reviewed; an explanation of the determination of the Basic Structural Hazard scores and modifiers; the criteria for selection of a cut-off Structural Score; and a list of the ATC-21 project participants.

# 2
# ATTRIBUTES OF AN IDEAL RAPID VISUAL SCREENING PROCEDURE

In order to evaluate existing RSP's, a set of criteria is required against which present RSP's can be judged. In this chapter, the attributes of such an "ideal rapid visual screening procedure" are presented. These ideal attributes have been determined based on a review of rapid visual screening procedures, as presented in the following sections, as well as the general experience of the project participants in conducting numerous field surveys and analyses of existing buildings. No single, currently available RSP satisfactorily incorporates all of the attributes indicated below.

*Applicability to All Building Types:* A rapid visual screening procedure for identifying seismically hazardous buildings should provide an initial assessment of the seismic hazard of individual buildings and therefore it should not be limited to one type of building structure. Rather it should be capable of identifying hazardous buildings of all construction types. For example, many rapid visual surveys have been limited to identifying unreinforced masonry (URM) structures, based on the assumption that these are the most hazardous buildings in the community. Although URM hazards have thus been identified, other (sometimes greater) hazards, for example, related to older tilt-up or non-ductile concrete buildings, have gone uncounted. Should the need arise, an RSP could be applied to only one structural category. However, all building groups should receive at least an initial limited-sample test screening in a portion of the community, to verify assumptions of which building type is the most hazardous. If these assumptions are verified, then selected building groups/areas may be targeted, for reasons of economy. The situation of, for example,

identifying all unreinforced masonry buildings and having no idea of the seismic hazards in the non-ductile reinforced concrete building group, or the house-over-garage building group, should be avoided.

*Quantitative Assessment:* Assessment of the hazard should be quantitative as it not only permits pass/fail decisions, but also provides a ranking system that may be used to set priorities within the "failed" category. A quantitative scheme also has the advantage of assuring a more uniform interpretation of the weights of "structural penalties" by survey personnel.

*Nonarbitrary Ranking System:* Although several of the studies reviewed do include quantitative approaches, these scoring systems are arbitrary and provide relative hazard assessments rather than an estimate of actual hazard based on physical parameters. A quantitative ranking system, which is useful for ranking structures for hazard abatement, should be nonarbitrary to avoid misleading results. The scores should be rationally based, and include uncertainty when possible. Their development should be clear so that new data can be incorporated as they become available and so that the scores can be modified for local building conditions.

*Supplemental Information:* As much as possible, supplemental information from building department and assessor's files, insurance (Sanborn) maps, previous studies and other sources should be collated and taken into the field in a usable format, for verification as well as to aid field personnel. Ideally, these data should be in a form so that information can be easily attached to each survey form as it is completed (e.g., a peel-off label or a computer-

generated form, with part identifying the building and containing pre-field data, and part to be filled out in the field).

*Earthquake Definition:* An important attribute is that the earthquake loading against which the capacity of the building is being judged be defined explicitly, preferably in physically based units such as acceleration. Otherwise it is unclear what "earthquake" loading the structures are being judged against and, further, the RSP is limited in its application to the region for which it was developed. Structures will have different damage potential in regions with different seismicity; thus a clear definition of the seismic demand should be included. Although a few of the available methods do include some explicit earthquake definitions, in most of these it is in the form of Modified Mercalli Intensity or Uniform Building Code zone. The complex questions of what earthquake loading a building should withstand and what the "acceptable risk" should be often require iterative solutions; therefore, it is possible that a re-screening could occur at a later time. Thus sufficient building-specific data should be recorded to permit adjustments should the input earthquake data be modified.

*Data Collection:* Organization of the data is an important part of an RSP. Specific details of structural type and configuration, site conditions, and non-structural aspects should be in a checklist format to avoid omissions. The data collection form should provide space for sketches, photos, and comments and should systematically guide personnel through the data recording procedure. Sketches and photos are invaluable for later reference. Both should be an integral part of the field data recording, because they are complementary. (A photo is data intensive, whereas a sketch emphasizes selected features, such as cracks, that may not be easily discernible on a photo of an entire building. In addition, requiring a sketch forces the surveyor to observe the building in a systematic fashion.)

*Systematic and Clear Criteria:* It is essential that an RSP, and the decisions deriving therefrom, be based on well-documented criteria and that "judgment" decisions be minimized. Although it is anticipated that survey personnel will have some interest in the elements of earthquake behavior of buildings and be capable of making subjective decisions when necessary, they should be provided with extensive written guidelines to avoid differing interpretations of the criteria for identifying hazardous buildings. Documentation should include many sketches as well as "inferences," or rules, to assist personnel in making decisions when information is uncertain.

*Age:* Age should be explicitly recorded. Often unavailable, age can be estimated, usually within a decade or two, on the basis of architectural style. Age can indicate whether a building is pre- or post- a specific "benchmark" year in the development of seismic codes for that building type. For example, in San Francisco, wood-frame buildings were required to be bolted to their foundations only since 1948. If a wood-frame building was built before 1948, it is likely that it is unbolted. These benchmark years differ by jurisdiction, but usually are locally known or can be determined.

*Condition:* State of repair is an important factor in seismic performance, and should be required to be noted, as it forces the survey personnel to look for problems such as cracks, rot, and bad mortar. Where relevant, this would include previous earthquake damage. Additionally, renovation should be noted, where possible. Renovation can be positive, because it indicates increased investment (which may have led to improvements in the structure), and/or negative, when it masks the true age of the structure. Additionally, renovation may have resulted in the removal and/or alteration of important structural members and thus may affect seismic performance. A common example is the "addition" of loading doors by saw-cutting of walls in tilt-up buildings, which actually removes seismic resistance.

*Occupancy:* Occupancy should be noted, as it is a factor in overall risk and may be required for subsequent decision making. How it will be factored into seismic hazard decision making is sometimes a difficult question. In some of the surveys reviewed, buildings were classified into high, medium, and low risk categories depending on the occupancy. This information was then used to rank the hazardous structures.

*Configuration:* Configuration issues should be noted and their contribution to the hazard quantified. It is clear from past experience that structural irregularities can be significant in the performance of a building during an earthquake. Many of these issues have been identified by Arnold and Reitherman (1981), and include items such as soft story, vertical and/or horizontal discontinuities, and irregularities of plan.

*Site Aspects:* Site aspects such as potential pounding between buildings, adjacent potentially hazardous buildings, corner buildings, and soil conditions need to be noted and quantified. By quantifying poor site conditions as "penalties," the survey personnel will have a uniform interpretation of the importance of each of the issues in the performance of the building.

*Non-structural Architectural Hazards:* Earthquake damage to building ornamentation or exteriors can lead to significant damage and/or life-safety hazard. Common examples include the fall of parapets, chimneys, and other overhanging projections.

*Personnel Qualifications:* Personnel background and training may prove critical to the results of an RSP. An ideal RSP should rely as little as possible on the need for extensive technical education or experience on the part of the personnel involved. Ideally, technician-level individuals (high school plus one to two years equivalent education/experience) should be able to perform the RSP, after one or two days of specialized training.

*Hazard Analysis Scheme:* Finally, for an ideal RSP the scheme for combining scores to identify the degree of seismic hazard for a building structure should be simple and fast, involving little or no field calculations beyond simple arithmetic.

The following chapters first present a summary of each of the RSP's identified, then evaluate them against the above "ideal" attributes, and finally, present a recommended procedure.

# 3

# SUMMARY OF EXISTING RAPID SCREENING PROCEDURES

A large number of methods for rapid analysis of seismically hazardous buildings can be found in the literature; however, these are generally abbreviated engineering analyses, requiring a trained engineer and access to the structural drawings. Only a few rapid visual screening methods have been found to exist, and none has had widespread practical application. Some of the available methods have been tested in limited areas for the purpose of refining the survey techniques but never have been applied to an entire community. In many cases the survey method that was chosen depended upon the ultimate use of the data that were gathered—for example, property loss estimation or life-safety estimation versus hazardous building identification. Thus, the different survey formats are in many cases a result of different goals, budgets, and personnel requirements.

This section presents citations and a summary of each RSP identified during the review of the literature, present practice, and community surveys. Each RSP has a brief acronym or other identifier (e.g., NBS 61 refers to the methodology developed at the National Bureau of Standards by Culver et al., 1975; OAKLAND study refers to a survey of buildings in the City of Oakland published in 1984), a bibliographic citation, and typically a one-paragraph summary overview of the methodology or study. The rapid screening procedures have been divided into two groups, surveys and methods, and are presented in reverse chronological order within each of these groups. Surveys are defined as those RSPs that have actually been applied to a real community. Methods are defined as those RSPs that are found in the literature, but as far as could be

ascertained have not been applied to any community. Comparisons of certain aspects of the methods are presented in tables in Chapter 4.

## SURVEYS

**City of Redlands Study.** Seismic Strengthening, Final Report and Handbook (1987). Report published by the Department of Economic and Community Development, County of San Bernardino, California. Also M. Green, personal communication.

> This handbook develops an RSP and presents a case study in the City of Redlands, California. The study was sponsored by the County of San Bernardino and the Southern California Earthquake Preparedness Project to identify potentially hazardous unreinforced masonry bearing wall buildings and to encourage voluntary seismic strengthening. The visual survey is designed to be conducted by inspector level personnel, with data being entered on forms (provided herein in Appendix A). Initial survey target areas were chosen based on the density of suspect unreinforced masonry buildings. Design level, building configuration, non-structural hazards, and adjacencies were used to identify the hazardous buildings. The survey resulted in maps showing the distribution and location of hazardous buildings in the city. Buildings were then ranked using a chart of tolerability of failure versus probability of failure for each building. The ranking included occupancy information. In its present

form, the method is limited to URM bearing wall structures and is therefore too limited for an ideal RSP.

**San Francisco Study.** A Survey of Unreinforced Masonry Buildings in San Francisco (1987). Report by Seismic Investigation & Hazards Survey Advisory Committee, and Department of Public Works. F. Lew, personal communication.

This survey was conducted by the San Francisco Building Department (1985-1986) to identify all unreinforced masonry buildings in the city. An office phase employed Assessor's files, Sanborn maps and Parapet Safety Program files to identify pre-1950 non-wood construction (approx. 6000). Every street in the city was then visually screened by building inspectors to determine and confirm which buildings were unreinforced masonry. The result of the survey is a list of approximately 2100 unreinforced masonry buildings that will be used with a future ordinance specifying mitigation procedures and timetables. Factors such as building configuration, occupancy, age and size were noted, but this information was not used. Costs and level of effort are as follows: two inspectors full time for one year surveyed this city of 700,000 population for a total reported cost of $120,000 (including clerical support).

**ABAG.** Perkins et al. (1986). Building Stock and Earthquake Losses - The San Francisco Bay Area Example Report by the Association of Bay Area Governments (ABAG), Oakland, California.

This is a survey conducted to estimate the building inventory for nine San Francisco Bay Area counties for estimation of earthquake losses. Specific hazardous buildings were not identified; only estimates of the number and geographic distribution of buildings of

each type were provided. Hence, there is no well-defined methodology for identifying specific seismically hazardous buildings. Many of the data were collected from land use maps, interviews with local building officials, Sanborn maps, and previous studies. "Windshield" surveys were conducted by ABAG project staff and a graduate student in architecture to supplement data on building types and to identify seismically suspicious unreinforced masonry buildings in older downtown, commercial, and industrial areas.

**Stanford Project.** Thurston, H. M., Dong, W., Boissonnade, A. C., Neghabat, F., Gere, J. M., and H. C. Shah (1986). Risk Analysis and Seismic Safety of Existing Buildings. John A. Blume Earthquake Engineering Center, TR-81, Stanford University, Stanford, CA.

This expert-system based method has two steps: (1) Using a computer program, Insight 2 (termed an expert shell), a pre-field screening is performed on the basis of geology, ground motion (MMI), building importance, and vulnerability (furnished from building department and other sources). (2) If the pre-field screening warrants it, an inspection of the building including drawings and building access is performed. A numerical value for risk is assigned using an expert system built from the Deciding Factor shell. (Loosely defined, an expert-system is a computerized data base or "knowledge base" containing logic and rules that process input information to arrive at some conclusion. Ideally its logic is similar to the thought process of a human expert.) Palo Alto was used as a case study to validate the expert system by comparing its risk evaluations with those of experts. Sample data sheets are included herein in Appendix A. The use

of an expert system to supplement visually obtained survey data should make this method suitable for a larger target audience; however, in its present form the field survey is too detailed for a rapid visual procedure. In addition, the weighting scheme used to rank building hazard is subjective and not based specifically on damage-related data. This is an extension of earlier work by Miyasato et al. (1986).

Low-Rise Study. Wiggins, J. H., and C. Taylor (1986). Damageability of Low-Rise Construction, Vol. II & IV. Report by NTS Engineering for National Science Foundation, Long Beach, California.

> This is an NSF-supported project to develop a methodology to estimate earthquake losses in low-rise buildings. A rating scheme based on a maximum value of 180 points is used. This study is an extension of the method developed for the 1971 Long Beach study. The insurance industry is the primary user of this method. Data gathering, however, is not done by field inspectors. Instead a short questionnaire about relevant aspects of the structure is completed by the building owner and decisions are made from the responses. As such, this is not an RSP.

U.S.-Italy Workshop. Angeletti, P., and V. Petrini (1985). Vulnerability Assessment, Case Studies. US-Italy Workshop on Seismic Hazard and Risk Analysis (Damage Assessment Methodologies), Varenna, Italy, 73-100.

> Two methods are presented. The first, a subjective side walk survey, can be performed quickly (12–16 buildings/day per team), and the second is a more in-depth survey with quantitative vulnerability assessments (4–8 buildings/day per team). Both methods were tested on 490 buildings (379

masonry, 111 reinforced concrete) in Forli, Italy, in 1984, using 100 public technicians and 15 earthquake engineering experts and on 293 buildings (279 masonry, 14 reinforced concrete) in Campi Bisenzio. The results are in the form of histograms and maps of vulnerability classes.

Charleston Survey. Survey of Critical Facilities for the City of Charleston, South Carolina (1984-1985). M. Harlan, personal communication.

> This study, funded by FEMA, was conducted for the purpose of estimating structural vulnerability and loss of function for the Charleston area in the event of a large earthquake. The study was not used to identify buildings for seismic rehabilitation. Probable Maximum Loss (PML), was used as the measure of damage. (PML was defined by Steinbrugge (1982) as the "expected maximum percentage monetary loss that will not be exceeded for 9 out of 10 buildings.") All critical facilities were evaluated, totaling about 350 buildings. No non-critical facilities were reviewed. Copies of the survey forms and rating forms are included in Appendix A. The advantage of these forms is that they are in a check-off format, thus minimizing omissions. The disadvantage is that they are too long for a rapid visual procedure. This survey was much more detailed than an RSP. Building entrance and plan review were often necessary to determine the PML modifiers needed for Steinbrugge's method. The vulnerability report has not yet been published. Third or fourth year university engineering students performed the survey. Students were given one to two weeks of training before going into the field. Each student reviewed an average of 3 buildings per day. Cost data were not available.

**Palo Alto Survey.** Survey of Buildings for the City of Palo Alto (1984-85), F. Herman, personal communication.

In 1984-1985, a local jurisdiction (Palo Alto, California) developed an ordinance and a survey method to identify and cite seismically hazardous unreinforced masonry and other specified buildings. The survey focused on three types of structures: (1) unreinforced masonry, (2) pre-1935 construction with more than 100 occupants, and (3) pre-1976 construction with more than 300 occupants. Seismically hazardous buildings were identified, primarily based on age and type of construction, number of occupants, and present condition. A sidewalk survey conducted by civil engineering graduate students under the supervision of a building department official was supplemented with Sanborn maps, building department files, and information from a previous survey conducted in 1936. Hazardous buildings were cited and owners were given one to two years to submit a detailed structural analysis of the building for city review. Examination of the several sample data sheets (included in Appendix A) shows that very little site or structure-specific information was requested in the sidewalk survey. All information about configuration problems, nonstructural hazards, and building dimensions would be included in the remarks area at the discretion of the inspector. This is because the method was essentially pass/fail based on whether a building could be classified into one of the three categories described above.

**Oakland Study.** Arnold, C. A. and R.K. Eisner (1984). Planning Information for Earthquake Hazard Response and Reduction. Building Systems Development Inc., San Mateo, California.

This is an NSF-sponsored investigation by Building Systems Development and the University of California, Berkeley, of urban planning for seismic risk mitigation, using Oakland as a case study. The procedure was mainly a sidewalk survey of building exteriors following an initial screening using information from Sanborn maps, assessor's files, and building permits. The survey was conducted by graduate students in architecture with guidance from a registered architect. The final product was the identification of "seismically suspicious" buildings, determined mostly on the basis of structural system and configuration factors and, to some extent, occupancy. Some factors, such as non-structural hazards, were noted, but it is not clear that they were used in identifying the seismically suspicious buildings. The report does not specify how the collected data were combined to determine the hazard of a building and thus the method requires a great deal of technical judgment. An example of the data collection sheet used in the sidewalk survey is included in Appendix A. Although building types and occupancy classes are well defined, other information is loosely defined, possibly leading to a lack of consistency among different data collectors. The level of effort expended involved 2 graduate students in architecture, a total of approximately 350 hours for 2500 buildings, and an approximate cost of $20,000.

**Multihazard Survey.** Reitherman, R., Cuzner, G., and R. W. Hubenette (1984). Multihazard Survey Procedures. Report by Scientific Service, Inc., Redwood City, California, for FEMA. (R. Hubenette, personal communication).

This method, developed for FEMA and

adopted in FEMA technical report TR-84, is designed to apply to essential facilities necessary for disaster operations. The method identifies and quantifies, on a scale of 1 to 5, a building's vulnerabiliy to radiation, fire, earthquake, high wind, tornado, hurricane, and flood hazards. The vulnerability is determined from a combination of the resistance of the construction and the exposure of the building to the particular hazard, but this calculation is not done by the surveyor. All data are processed by computer at the national level (FEMA). The method has been adopted and implemented since 1985 in many states, including California, Florida, North Carolina and Arizona. However, the priority for the multi-hazard surveys is civil defense related, and in many cases the earthquake portion of the survey is not performed. All survey data are collected on a standardized form (included in Appendix A) and are entered in a national database. The data collection form is organized to facilitate the computerized data processing, but it is difficult to follow. Rather than a checkoff format, the form requires the use of numerical codes that are not easily memorized. One of the promising and unique features of this method is that inference rules are provided for cases when visual inspections, drawings, and other supplemental information are not adequate to positively answer survey questions. The method is more detailed than an RSP, as building entrance is necessary and sometimes plans are reviewed. The survey can take from one hour to three days per building. Survey personnel need a minimum of two years undergraduate technical background. Cost information was not available.

**New Madrid Study.** An Assessment of Damage and Casualties for Six Cities in the Central United States Resulting from Two Earthquakes, M=7.6 and M=8.6, in the New Madrid Seismic Zone (1983). Report by Allen & Hoshall, Inc., Memphis, Tennessee, for FEMA.

This study, also known as the Six Cities Study, assesses damage due to earthquakes on the New Madrid fault zone. An extensive inventory of buildings was supplied by FEMA for the six project cities. These data were checked and in some cases supplemented by visits to the sites by a structural engineer and an engineering technician. In other cases, the data were verified by telephone contact with facility managers. The inventory was limited to a few representative structures of well-defined classes such as hospitals, critical structures, transportation systems, public utilities, and schools, and was primarily to assess the type of construction for each of the classes. Three different survey forms were available depending on the class of the structure and information required (see Appendix A). This is not a rapid visual screening procedure, but a sampling procedure to infer the properties of the larger building inventory for use with fragility curves to estimate damage. Cost information was not available.

**OSA Hospital Survey.** Earthquake Survivability Potential for General Acute Care Hospitals in the Southern California Uplift Area (1982). Report by Office of the State Architect for Office of Statewide Health Planning and Development, California. J. Meehan, personal communication.

This inventory and evaluation of hospitals in the Palmdale Bulge area were done by structural engineers from the Office of the State Architect. Hospitals were classified into six

"survivability index" categories from A (low risk) to F (high risk) based on the date of construction and structural information. The criteria used in this survey require extensive engineering judgment and are specific to hospitals as they are based on adherence to Titles 17 and 24 of the California Administrative Code. Data were gathered by extensive interior and exterior visual inspections along with an in-depth review of construction drawings when possible. Level of effort was probably one to two engineer-days per hospital, depending on the complexity. This was not a rapid procedure, but rather a detailed inventory of hospital resources, such as beds and rooms, as well as anchorage of equipment and availability of emergency services.

Los Angeles Study. Survey of Unreinforced Masonry Bearing Wall Buildings (1978-1979) for the City of Los Angeles. E. Schwartz, personal communication.

This study in the City of Los Angeles was performed by city building inspectors during 1978-1979 for the purpose of identifying bearing wall unreinforced masonry buildings, but not infill or other types of URM. Preliminary identification of pre-1934 URM was performed using assessor's files, Sanborn maps, and records from a previous parapet stabilization program, resulting in identifying about 20,000 potentially hazardous buildings. A block-by-block visual survey of building exteriors (and interiors when possible) reduced this to a final count of about 8,000 hazardous buildings. Although configuration and state of repair were noted, the primary criterion used to identify the hazardous buildings was the existence of unreinforced masonry bearing walls. An average of 40 minutes was spent at each building. After the data

were collected, hazardous buildings were placed in one of four classes: (1) essential buildings, which were mostly state- or city-owned; (2) high-risk buildings, with more than 100 occupants and/or few interior walls; (3) medium-risk buildings, defined as having 20 to 100 occupants and/or many interior partitions; and (4) low-risk buildings, those buildings with less than 20 occupants. These categories were used to prioritize the mitigation procedures. The level of effort expended involved 6 inspectors, 1 senior inspector, 1 structural engineer, 2 clericals, all for 2 years, at a cost of approximately $400,000.

University of California Study. McClure, F. E. (1984). "Development and Implementation of the University of California Seismic Safety Policy." Proceedings, Eighth World Conference on Earthquake Engineering, San Francisco, 859-865. F. McClure and L. Wyllie, personal communication.

In response to the 1975 seismic safety policy implemented by the University of California, a survey of buildings with area greater than 4,000 sq ft and with human occupancy was conducted by experienced structural engineers (Degenkolb Associates were consultants on this project). Based on structural, non-structural and life-safety judgments, a seismic rating of good, fair, poor, or very poor was assigned by observations of building exteriors and a review of design drawings and previous engineering reports. Two to four days were spent on each of 9 campuses, for a total review of 44 million sq ft, of which 21% rated poor or very poor. The effort was split between reviewing drawings and on-site inspection. There were no formal criteria in this study, as decisions were made on a building by building basis. A considerable amount of

judgment and engineering experience was required to perform this survey.

**Santa Rosa Study.** Identification of Seismically Hazardous Buildings in Santa Rosa, 1971-present. W. E. Myers. personal communication. Also, Myers, W. E. (1981). "Identification and Abatement of Earthquake Hazards in Existing Buildings in the City of Santa Rosa." Proceedings, 50th Annual SEAOC Convention, Coronado, CA, 55-66.

This study arose from an ordinance adopted by the Santa Rosa City Council in 1971 to review all buildings constructed before December 31, 1957 (one and two-story wood frame, single family dwellings were exempt from the review process). A preliminary review is performed by a city official (experienced structural engineer) to determine if further review is necessary, based on whether the building complies with the 1955 UBC. Any further review is the responsibility of the building owner and must be prepared by a structural or civil engineer. The initial screening consists of a half day (on average) detailed site inspection involving entry into the building, including the basement, attic, and other portions of the building, noting such features as wall ties, openings, and diaphragms. Fire as well as earthquake-related hazards are usually identified. Data are collected using a handheld tape recorder, and later transcribed. Where possible, plans are examined, although in many cases they are unavailable. In a few cases rough calculations are performed. Subsequently a report is written (2 to 20 pages depending on the complexity of the structure) and submitted to the owner with a timeline for mitigation. The established priority of review was based on the number of occupants, buildings with the most occupants being reviewed first. Reviews began in 1972 on churches and other

buildings with assembly occupancy greater than 100 persons, and in 1987 the city was reviewing buildings with smaller occupancy such as office buildings and retail stores. Between 1972 and 1987, approximately 400 buildings were initially reviewed (out of approximately 600 in the city) with about 90 percent requiring further review. Due to the detailed nature of the visual inspection and the level of engineering expertise required, this does not fulfill the definition of an RSP. The level of effort expended was: 1 full-time engineer employed by the city for 15 years, and a cost of approximately $500 per building.

**Long Beach Study.** Wiggins, J. H., and D. F. Moran (1971). Earthquake Safety in the City of Long Beach Based on the Concept of Balanced Risk. Report by J. H. Wiggins Co., Redondo Beach, California. Also E. O'Connor, personal communication.

This study was developed as part of a model ordinance (Subdivision 80) for the City of Long Beach. It was a significant advancement in the techniques of rapid identification of seismically hazardous buildings. In the original methodology, five factors were scored and combined to form a hazard index: (a) framing system/walls, (b) diaphragm/bracing, (c) partitions, (d) special hazards, and (e) physical condition. A score of 0–50 indicated rehabilitation was not required; 51–100 indicated some strengthening was required; and 101–180 indicated a serious life hazard existed. This widely known method was not directly employed by Long Beach but was modified in the ordinance to score the following five structural resistance factors for unreinforced masonry: (a) wall stability, (b) wall anchorage, (c) diaphragm capacity, (d) shear connection capacity, and (e) shear or moment resisting element capacity. Occupancy,

importance and occupancy potential factors were also included. A survey of 928 pre-1934, type 1, 2 or 3 buildings was conducted by city building inspectors over several years. Deadlines for hazard mitigation depend on the ranking provided by the hazard index.

## METHODS

**Seismic Design Guidelines for Upgrading Existing Buildings (A Supplement to "Seismic Design Guidelines for Buildings") (1986). Dept. of the Army.**

This is a methodology developed for the Army that contains both a rapid visual component and a detailed structural analysis. The result of the visual survey is a list of buildings that should be further reviewed. The first step is to eliminate buildings from the survey inventory using eight prescribed criteria. The remaining buildings are then classified as (1) essential, (2) high risk or (3) all others. All available design criteria such as drawings, calculations, and specifications are compiled and pertinent information is transferred to the screening form (Appendix A). A field survey is then performed, allocating 10 to 30 minutes per building. Buildings are eliminated from the list if it would not be feasible or cost effective to upgrade them, or if they are identical to other structures that will be reviewed.

**ATC-14, (ATC, 1987). Evaluating the Seismic Resistance of Existing Buildings. Applied Technology Council, Redwood City, California.**

Although this extensive methodology contains no rapid visual screening aspect, it is included in this review because Section 4.2.2 and Appendix C of ATC-14 contain checklists of features that, if elaborated, could form the basis

for an RSP. Moreover, buildings identified by the ATC-21 methodology as seismically hazardous should be reviewed in detail with the methodology presented in the ATC-22 Handbook (in preparation), which is based on the ATC-14 methodology.

**A Methodology for Seismic Evaluation of Existing Multistory Residential Buildings. U.S. Department of Housing & Urban Development, 3 volumes. Pinkham, C. W., and G. C. Hart (1977).**

This method is based on NBS 61 (described below); however in this case only Masonry B (UBC 73, sections 2414, 2415 and 2418) and Masonry A (all other concrete or brick masonry) are targeted. This is essentially a rapid analysis procedure with a preliminary visual screening component. The data collection forms are the same as those for NBS 61. However, the criteria for preliminary screening are not well defined and therefore require a good deal of judgment.

**NBS 61. Culver, C. G, Lew, H. S., Hart, G. C., and C. W. Pinkham (1975). Natural Hazards Evaluation of Existing Buildings, BSS 61, National Bureau of Standards, Washington, D.C.**

This is an extensively developed methodology, designed for building officials and engineers, to evaluate existing buildings for major natural hazards: earthquake, high wind, tornado, and hurricane. Evaluation of existing buildings is performed in three levels, the first of which is a simple visual procedure, providing input to several simple equations that result in a Capacity Rating (CR). This method has been widely referenced but not directly or explicitly applied to any region, as far as could be determined. Data collection forms and field evaluation forms are

included in Appendix A. It can be seen that the data collection forms are quite extensive and assume that the inspector will have access to the interior of the building and to soils and geologic reports; thus, this is not a true sidewalk survey. Bresler et al. (1975) point out that the weights employed and the algorithms or equations for determining the capacity ratio (see field evaluation forms) are arbitrary and gave misleading results for a trial building they examined.

Not included in this list are earthquake loss estimation studies such as those prepared by the federal government for the Los Angeles area (NOAA, 1973), Salt Lake City area (USGS, 1976), San Francisco Bay area (NOAA, 1972), and Puget Sound, Washington, area (USGS, 1975).

# 4

# EVALUATION OF EXISTING RAPID SCREENING PROCEDURES

This section evaluates the previously discussed RSPs and studies according to several broad categories. Because each method/study reviewed was unique in some aspects, the following broad categories within which to compare and comment on the detailed aspects were defined:

- Organizational
- Structural
- Configuration
- Site and Non-structural
- Personnel

These five broad categories were selected as being of greatest interest to one or several segments of the target audience. To facilitate comparison, a tabular format has been used. Within each category specific items were noted, as were whether a specific RSP method or study addressed this issue, employed this data item, or simply noted this item. Where an entry is blank, no information was available.

**Organizational**—Refers to the general aspects of an RSP method or study that would be of interest to a person or organization implementing and managing a survey of a community. These include items such as the size of the survey defined by number of buildings, population and/or area; the types of buildings that were targeted; and whether graphic methods (sketches or photos) were used to record data.

**Structural**—Refers to structure-specific data items that would be of most interest and use to a structural engineer (e.g., age, structural material).

**Configuration** —Includes items such as whether an RSP method or study specifically

noted soft stories or irregular building configuration. This would be of interest and use to architects and engineers.

**Site and Non-Structural**—Includes items related to the site (e.g., soil conditions, potential for pounding), and to the non-structural aspects of a building that may either pose a hazard (e.g., parapets) or may affect structural behavior (e.g., infill walls).

**Personnel**—Addresses two aspects regarding the qualifications of the personnel who would employ the specific RSP or study being evaluated: (1) What were the backgrounds or qualifications of the personnel who conducted the study or for whom the method was intended? (2) Could the method be applied by each or any segment of the target audience?

After reviewing all the existing surveys and available data, it becomes clear that there is currently relatively little statistical information relating damage to all types of structures under different levels of earthquake loading. Although general statements about the behavior of buildings in earthquakes can be made, it is difficult to quantify the damage. Even general statements about vulnerability based on building type are subject to question because so many other aspects such as configuration, connection detailing or local site conditions can contribute to poor structural performance. Reitherman (1985) noted that architectural configuration can be quite different from structural configuration and thus can be very misleading without access to structural drawings. Structural detailing, which can be so critical to good performance, is difficult to "score" from purely visual inspections. For these reasons, the results of an RSP cannot be regarded as definitive, and

structural adequacy or lack thereof can only be determined on the basis of detailed examination by a registered professional engineer.

## 4.1 Organizational Aspects

Table 1 presents the evaluation of the organizational aspects of the various methods/studies. Specific items considered are discussed below.

**Building Groups Targeted:** Most methods or studies begin by eliminating some building types as non-hazardous (e.g., wood-frame construction), and limiting themselves to simply identifying that building type considered "most hazardous" (e.g., URM), or they have a well-defined list of structural types in their evaluation methodology. This report identifies those building types that were addressed.

**Survey Area:** In the case of studies where buildings in a community were actually screened, some measure of the size of the project, such as number of buildings, area, population, or other measure, is indicated.

**Number of Hazardous Buildings Identified:** As above, where available, the number of hazardous buildings actually identified for the particular study is indicated.

**Method:** A brief description of whether the method/study (i) simply employed a pass/fail measure (e.g., is or is not URM), or (ii) employed subjective measures and techniques (e.g., has a soft story, is irregular) without quantifying these items, or (iii) employed numerical scoring schemes and algorithms for combining information to arrive at a quantified measure (e.g., tension-only bracing or long-span diaphragms are given weights and these are "scored" in some fashion).

**Supplemental Information Employed:** Was non-visual off-site information employed, such as from building department, assessor files, Sanborn maps, or previous studies?

**Explicit Earthquake Definition:** Was the "earthquake loading" explicitly defined? Many times a method/study determined that buildings were seismically hazardous without clearly defining what ground motions the building was being compared against. Admittedly, for a specific jurisdiction this might be implicitly clear (e.g., a repeat of the 1906 event for San Francisco), but this aspect would need clear definition for any general RSP.

**Sketch or Photo:** Sketches or photos as an integral part of the data recording are invaluable for later reference. Requiring sketches assures that the survey personnel methodically observe the building.

## 4.2 Structural Aspects

Table 2 presents an evaluation of the methods/studies for the structural aspects. Specific items considered are discussed below.

**Age/Design Level/Building Practice:** Building age is usually an explicit indicator of the design level or the code under which the building was designed, and the building practices prevalent at the time of construction.

**State of Repair:** Maintenance and general conditions are important aspects of structural adequacy since corrosion and deterioration decreases structural capacity.

**Occupancy Factor Definition:** Occupancy is not an explicit factor in structural adequacy, but is important in setting priorities.

**Material Groups:** Broad structural material groupings can be noted in a variety of ways, and are a basic measure of seismic capacity.

**Number of Stories/Dimensions:** Number of stories and/or the plan or other dimensions are a broad indicator of structural dynamic properties, as well as of value.

**Symmetrical Lateral Force Resisting System:** The degree of symmetry of the lateral

force resisting systems (LFRS) is an important clue as to adequacy of load path. If this was an item of interest to the survey team, what guidelines were they given for identifying the LFRS? If noted, how was the degree of symmetry employed?

**Member Proportions:** Were these noted in any way? Relatively thin member proportions are a general indication of potential problems in connections and/or member stability and, for concrete members, usually indicate non-ductile detailing.

**Sudden Changes in Member Dimensions:** Drastic changes in column dimensions can sometimes be observed through windows, and would indicate upper story "softness." Were these noted?

**Tension-only Bracing:** Was this relatively non-ductile behaving system identified as an item to note if observed?

**Connections Noted:** Was any attention paid to connections, as for example whether special wall/diaphragm ties were present in bearing-wall systems (e.g., tilt-up, URM)?

**Previous Earthquake Damage:** In areas where previous earthquakes might have weakened a building, was any attempt made to look for indications of this damage?

**Renovated:** Was there any indication that the building had been renovated, either with regard to architectural (thus obscuring the age) or structural details?

### 4.3 Configuration Aspects

Table 3 presents an evaluation of the methods/studies for the configuration aspects. Specific items considered are discussed below.

**Soft Story:** Abrupt changes and/or decrease in stiffness in lower stories of a building lead to large story drifts that cannot be accommodated. Was this consideration incorporated into the determination of seismic

hazard, or was it noted by survey personnel but not used? Similarly, were plan irregularity, vertical irregularity, excessive openings and aspect ratio of the building or its components (vertical or horizontal) considered?

**Corner Building:** Buildings on corners typically have potential torsional problems due to adjacency of two relatively infilled back walls, and two relatively open street facades.

### 4.4 Site and Non-structural Aspects

Table 4 presents an evaluation of the methods/studies for the site and non-structural aspects. Specific items considered are discussed below.

**Site-Related:** So-called "adjacency" problems of pounding and/or the potential for a neighboring building to collapse onto the subject building are important structural hazards. These are two aspects that can be easily observed from the street and that the 1985 Mexico City experience again emphasized as critical. These were placed under site-related rather than structural or configuration because they involve aspects that are more related to the site and adjacent buildings than to the subject building per se.

Soil conditions or potential for seismic hazards other than shaking, such as landslide or liquefaction, are also very significant factors related as much to the site as to the structure. Admittedly, these non-shaking hazards may more easily be defined on the basis of reference maps than in the field, but in the methods reviewed were these given any consideration at all? Were soft soil/tall building or stiff site/stiff building correlations attempted as a crude measure of resonance/long period potential?

**Non-Structural:** Were major infill walls and/or interior partitions and their potential effects on structural behavior, especially in light buildings, noted? Were the special and relatively obvious seismic hazards of cornices, parapets,

chimneys and other overhanging projections noted?

## 4.5 Personnel Aspects

Table 5 presents an evaluation of the methods/studies for the personnel aspects. For most projects, cost information was difficult to obtain and was usually based on criteria that are not easily compared. Some data provided included clerical and report production costs, others only the costs of survey personnel. This report provides personnel time per building reported for a particular RSP. By multiplying by labor cost, and including other expenses such as transportation and report production costs, the reader can estimate what a particular RSP would cost if applied to a particular community. Whether or not the particular RSP is appropriate for use by each segment of our target audience is indicated (by Y or N).

## 4.6 State of the Practice

Information provided by about a dozen practicing structural engineering firms, mostly in California, indicates that no rapid visual screening procedure is currently being used by practitioners. Typically, structural engineers have used visual screening procedures as a preliminary phase of a more detailed analysis. However, because most of the procedures involved entrance into buildings and detailed inventories of structural elements and non-structural elements, these procedures do not fit the definition of "rapid visual screening" utilized herein.

"Subjective judgment" is the type of criteria used most extensively to classify seismically hazardous buildings; in only a few cases have quantitative criteria been developed. However, in most cases, studies have been for planning purposes, and engineers have tried to include some qualitative indicator of the degree of hazard of the building to assist in setting

priorities for mitigation procedures. In general, the surveys have been performed by experienced engineers or by entry-level engineers accompanied by a more experienced engineer. Most often, junior personnel have been given brief training as to what to look for and a checklist or data collection form, usually without detailed written guidelines. In some cases, a trial run through a building with the data collection forms was performed under the supervision of an experienced engineer. Usually there were no structured guidelines for identifying a building as one structural type or another, nor was there any consistent way to incorporate the uncertainty in the judgments that were made. Consequently, the variability in backgrounds and experience of the personnel and the lack of detailed guidelines can result in widely differing interpretations of the criteria for identifying hazardous buildings and hence produce inconsistent results.

## 4.7 Conclusions

The foregoing review indicates that no currently available RSP method or study addresses all of the major aspects fundamental to seismic hazard, and further that no really satisfactory RSP method or procedure exists. Most omit many of the described aspects, and/or are very subjective in their treatment of the data recorded. In many cases, too much reliance is placed on the experience of the survey personnel, with little attention paid to consistency among different personnel. Further, although the personnel may have been given some coaching or training in what to look for, this was usually unsystematic and omitted major aspects.

Most of the rapid visual screening procedures that were reviewed were developed for a particular municipality and thus were applied in only one geographic region. None addresses the issues of regional differences in construction practices and building code regulations. The multihazard study (Reitherman

et al., 1984), NBS 61 (Culver et al., 1975) and the Navy Rapid Seismic Analysis Procedure are designed for nationwide application, but these procedures do not specifically discuss differences in building performance that might result from regional engineering and construction practices. In addition, they involve entrance into the building or calculations and thus are too detailed for an RSP.

From the studies that were reviewed and from experience with earthquake-related damage, a set of attributes of a satisfactory RSP method was developed:

1. The earthquake loading against which the building's capacity is being judged should be explicitly defined, preferably in physically based units (e.g., acceleration). The anticipated earthquake loading is defined in several of the studies such as NBS 61, the Stanford Project, the University of California Study, the OSA Hospital Survey, the New Madrid Study and the Multihazard Survey; however, non-physical units such as UBC zone or MMI are used. Only in Wiggins and Moran (1971), and Wiggins and Taylor (1986) is the use of maximum expected bedrock acceleration discussed. Because the decision of what ground motion a building should satisfactorily withstand involves not only geotechnical and seismological issues but also difficult questions of acceptable risk, the "acceptable earthquake" may often be decided in an iterative fashion. Thus, sufficient building-specific data should be clearly recorded to permit later calculations for the purposes of re-screening, given a different "earthquake loading."

2. As much as possible, supplemental information compiled from building department and assessor's files, Sanborn maps and other sources should be collated and taken into the field in a usable format, such as computer listings or peel-off labels that can be affixed to the survey form, for verification as well as aiding the field personnel. Most of the methods that were reviewed use other sources of information to supplement the visually obtained data.

3. An RSP should have the capability to survey and identify hazardous buildings of all types. In some cases, jurisdictions may wish to use the RSP in a limited form for certain "high hazard" target buildings or areas. However, all building groups should receive at least an initial limited-sample-area test screening to verify assumptions of which building type is the most hazardous within the local building stock. If these assumptions are verified, then selected building groups/areas may be targeted for reasons of economy. However, the situation of having identified all URM buildings, and having no idea of the seismic hazards in the older non-ductile reinforced concrete building group, for example, or the older unbolted house-over-garage (HOG) building group, should be avoided.

4. A quantitative approach, as exemplified in the Long Beach study (Wiggins and Moran, 1971) or NBS61 (Culver et al., 1975), appears preferable, as it not only permits pass/fail decisions, but also allows prioritization within the "failed" category. However, the quantitative "scoring" should not be arbitrary but rather should be rationally based, as far as possible.

5. Sketches should be an integral part of the data recording to assure that the survey personnel methodically observe the building. Sketches and photos are invaluable for later reference, and ideally both should be part of the field data

recording because they are complementary. Several of the reviewed methods omitted a sketch or photo.

6. Age should be explicitly recorded. Although often unavailable, age can be estimated, usually to within a decade or two, on the basis of architectural style, and thus can indicate whether a building is pre or post a specific "benchmark" year in the development of that building type. For example, in San Francisco, wood-frame buildings were required to be bolted to their foundations only since 1948. If a wood-frame building is pre-1948, it is likely to be unbolted. Similarly, unreinforced masonry was not permitted after the adoption of the 1948 building code. Thus, in a survey of hazardous buildings in San Francisco, only pre-1950 buildings were considered. These benchmark years differ by jurisdiction, but are usually locally known or can be determined and should be included in training material for survey personnel.

7. State of repair should be explicitly noted, as it forces the survey personnel to look for cracks, rot, corrosion and lack of maintenance. Although the state of repair was noted in many of the methods reviewed, it was not formally used in identifying the seismically hazardous buildings.

8. Occupancy (use) and number of occupants should be noted, using standardized occupancy categories. In the Los Angeles and Long Beach studies, occupancy was used to prioritize buildings for hazard abatement.

9. Specific observable details of structural members, structural hazards and foundation and site conditions should be itemized in a check-off format, to avoid omission.

10. Configuration issues should similarly be considered, but their contribution to seismic hazard must be quantified, at least on a weighting basis. Although some of the methods, such as NBS 61, have addressed configuration problems the scoring systems are subjective and are not based on actual damage-related data.

11. Site aspects of pounding, corner building and adjacencies, and non-structural aspects, need to be similarly noted. Few of the methods have used pounding, corner buildings, or adjacencies as criteria for identifying hazardous buildings, although these problems were noted. Several studies (e.g., City of Redlands, Multihazard Survey, NBS 61) consider non-structural hazards explicitly as part of their criteria.

12. Personnel should have adequate background and training to understand the earthquake behavior of buildings because many of the data they will be called upon to record will involve subjective decisions. In addition, the survey should be accompanied by detailed guidelines as to what to look for and how to interpret and indicate uncertain data to avoid inconsistencies in the data collection. The guidelines presented in the Multihazard Survey are useful examples.

13. Data recording should be complete and systematic. A field remote-entry electronic format (i.e., a "laptop" computer) should be considered, although for economic reasons a clipboard has many advantages.

14. Because information is often lacking, uncertainty considerations must be incorporated into the methodology, although it can be relatively "invisible." For example, building type may be

indicated as (circle as appropriate):

RCMRF[*] : definite likely possible unlikely
RCSW:         definite likely possible unlikely
URM:          definite likely possible unlikely

with weights assigned to each, on the basis of their "contribution" to seismic hazard. If it is likely that the building is an RCSW but possible that it is a URM, then the weighting would result in a higher seismic hazard than if the survey personnel were called upon to provide only one typing. The weighting and arithmetic do not need to be performed in the field, although it may be advantageous to have the weighting known to the field personnel.

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*RCMRF:    Reinforced concrete moment-
           resisting frame
 RCSW:     Reinforced concrete shear wall
 URM:      Unreinforced masonry

Table 1
ORGANIZATIONAL ASPECTS

| PROCEDURE/ Source | Building Groups Targeted | Survey Area (Size, number of buildings, population) | Number of Hazardous Buildings Identified | Method: Pass/Fail, Subjective, Quantitative? | Supplemental Information Employed? | Explicit Earthquake Definition | Sketch or Photo? |
|---|---|---|---|---|---|---|---|
| CITY OF REDLANDS/ Mel Green & Assoc. (1986) | Bearing wall URM | Test survey approximately 200 buildings | Appoximately 160 buildings | Quantitative | Aerial photo Sanborn maps | N | Y |
| SAN FRANCISO/ Frank Lew | URM pre-1950 construction | Entire city, population 700,000 | 2100 from initial 6000 | Pass/Fail | Assessors' files, Sanborn maps, Parapet Safety Program files, owner feedback | N | N |
| ABAG/ J. Perkins et al. (1986) | WF, URM, RM, LM, TU, MH | 6,000 square miles, population 5.5 million | 4700-5700 | Subjective | Sanborn maps, Land use maps, interviews with local building office, previous studies | N | N |
| STANFORD PROJECT/ JABEEC TR 81, Thurston et al. (1986) | All 27 defined classes | Phase I Entire city population 50,000 | Phase I 4 sub-areas of city identified as most hazardous | Subjective and Quantitative | Palo Alto Comprehensive Plan Building Department input | MMI | Y, sketch |
| LOW-RISE/ Wiggins and Taylor (1986) | low rise | N/A | N/A | Quantitative | N | Maximum expected bedrock acceleration | Y |
| PALO ALTO/ F. Herman | URM, pre-1976, pre-1936, TU | 2000 focus on older commercial | 325 | Pass/Fail | Sanborn maps building permits, previous study, owners | N | N |

Table 1
(continued)

| PROCEDURE/ Source | Building Groups Targeted | Survey Area (Size, number of buildings, population) | Number of Hazardous Buildings Identified | Method: Pass/Fail, Subjective, Quantitative? | Supplemental Information Employed? | Explicit Earthquake Definition | Sketch or Photo? |
|---|---|---|---|---|---|---|---|
| OAKLAND/ Arnold, Eisner (1980, 1984) | URM, WF ND-RC | Approximately 2000, Oakland Central Business District | 377 approximately | Subjective, no clear definition of seismically suspicious | Y Sanborn maps, building permit, previous study, assessors' files | N | Photo, building plan, sketch |
| MULTIHAZARD/ FEMA & Reitherman et al. (1984) | Essential facilities, definition left to local jurisidiction All types | About 10,000 buildings since 1975 | Unknown | Quantitative | Maps, construction drawings | UBC zone | Y |
| NEW MADRID/ Allen & Hoshall (1983) | All | Six couties population 1 million, approximately 2,400 buildings | N/A | Subjective, damage states | FEMA data | Y M = 7.6 & M = 8.6 MMI used for damage estimate | N |
| OSA HOSPITAL/ (1982) | Hospitals, all types of construction | 1077 | 100 in classes E & F "low survive index" | Subjective | Building plans | UBC zone | Unknown |
| LOS ANGELES/ (1978-79) | URM | Entire city population 3 million, 490 square miles | 8,000 approximately | Pass/Fail | Y Sanborn maps assessors' files, previous studies | Not explicit (large Ep.) | 2 photos per building, sketch |

Table 1
(continued)

| PROCEDURE/ Source | Building Groups Targeted | Survey Area (Size, number of buildings, population) | Number of Hazardous Buildings Identified | Method: Pass/Fail, Subjective, Quantitative? | Supplemental Information Employed? | Explicit Earthquake Definition | Sketch or Photo? |
|---|---|---|---|---|---|---|---|
| UNIVERSITY OF CALIFORNIA/ McClure (1984) | Area greater than 4,000 square feet, human occupancy | 44,000 square feet, approximately 800 buildings | 9,000 square feet of Poor or Very Poor | Subjective | Previous studies, design drawings | MMI > IX | Y |
| SANTA ROSA/ Myers (1981) | All types built before 1958 | About 400 buildings since 1972 | About 90% for further review | Subjective | Plans | N | Photos and sketches |
| LONG BEACH/ Wiggins and Moran (1971) | Pre-1934 type 1, 2, 3 | Entire city, population 500,000 | 938 | Quantitative | Y Sanborn | N for LB study Y for Wiggins method (maximum expected bedrock acceleration) | Y |
| NBS 61/ Culver et al. (1975) | SB, DF, SW, CSF, RF, CSW, MSW, WF, 11 building frame types | N/A | N/A | Subjective and Quantitative (Capacity Ratio Rating) Structure Structure rating vs. MMI's | Suggest use of original drawings or soil reports, Sanborn maps | UBC zone, MMI levels > V | Building elevations and site plan with adjacencies, Photo suggested |

Table 2
STRUCTURAL ASPECTS

| PROCEDURE/ Source | Age/Design Level/ Building Practice | State of Repair | Occupancy Factor Definition | Material Groups | Number of Stories/ Dimensions | Symmetrical LFRS | Member Propor- tions | Sudden Changes in Member Dimensions | Tension- only Bracing | Connections | Previous Earthquake Damage | Renovated |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CITY OF REDLANDS/ Mel Green & Assoc. (1986) | Y | Y | Y | URM | Y | N | N | N | N | Y | N | Y |
| SAN FRANCISCO/ Frank Lew | Y | N | N | URM | Noted, from assessor file | N | N | N | N | N | N | N |
| ABAG/ J. Perkins et al. (1986) | N | N | Y noted for some | Concrete Steel Wood Masonry | Y | N | N | N | N | N | N | If available |
| STANFORD PROJECT/ JABEEC TR 81, Thurston et al (1986) | Y | Y | Y essential facility or large number of occupants, residential, commercial or industrial | Steel Concerete Masonry Wood | Y noted number and dimensions | Y | N | Y | Y | Y | Y | Y |
| LOW-RISE/ Wiggins and Taylor (1986) | Noted, implicit in some of rating criteria | Y | Noted | Concrete Steel Wood Masonry | Y | Y | N | N | Not explicit, noted inadequate or in- complete bracing | Y | Y noted unrepaired earthquake damage | N |

Table 2
(continued)

| PROCEDURE/ Source | Age/Design Level/ Building Practice | State of Repair | Occupancy Factor Definition | Material Groups | Number of Stories/ Dimensions | Symmetrical LFRS | Member Propor- tions | Sudden Changes in Member Dimensions | Tension- only Bracing | Connections | Previous Earthquake Damage | Renovated |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PALO ALTO/ F. Herman | Y | Noted but not formally employed | Y (number persons) | URM, TU | Noted but not formally employed | N | N | N | N | N | N | N |
| OAKLAND/ Lagorio, Arnold Eisner (BSD, 1984) | Y | Noted but not formally employed17 | Noted importance of structure use codes | URM, TU ND-RC, mixed | Noted | N | N | Noted | N | N | N | Noted |
| MULTIHAZARD/ FEMA & Reitherman et al. (1984) | Y | Y | Noted use | Many classes | Y | Strong beam, weak columns | N | N | Y | Roof/wall and anchor bolts | N | Y |
| NEW MADRID/ Allan & Hoshall (1983) | Y | N | Y | Steel Concrete Masonry Wood | Y | N | N | N | N | N | N | N |
| OSA HOSPITAL/ (1982) | Y Building code jurisdiction | Y | Y Noted building use, Not included in ranking | Concrete Steel Masonry Wood | Y | Y | N | Y | Y | N accessed from plans | Not sure | Y |
| LOS ANGELES/ (1978-1979) | Y | Noted cracks & mortar condition | Y Table 33A UBC | URM | Y | Noted | N | N | Noted from parapet program | N | Noted | Noted from parapet program |

Table 2
(continued)

| PROCEDURE/ Source | Age/Design Level/ Building Practice | State of Repair | Occupancy Factor Definition | Material Groups | Number of Stories/ Dimensions | Symmetrical LFRS | Member Propor- tiosn | Sudden Changes in Member Dimensions | Tension- only Bracing | Connections | Previous Earthquake Damage | Renovated |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UNIVERSITY OF CALIFORNIA/ McClure (1984) | Y | Noted but not significant in ranking | N | Concrete Steel Wood Masonry | Number stories dimensions from plans | Y | Y | Y | Y, not much found | Sometimes | At a few campuses | Y |
| SANTA ROSA/ Myers (1981) | Y | Y | Noted but not included in decision | No formal groups defined All types examined | Y | Y | N | Y | Y | Y | Y | Y |
| LONG BEACH/ Wiggins and Moran (1971) | N | Y | N, noted but not formally employed | RC, S, W, URM, RM | Y | Y | N | N | N | N | Y i.e., state of repair noted | N |
| NBS 61/ Culver et al. (1975) | Y noted but not formally employed | Y evidence of past damage repair noted | N noted but not formally employed | Concrete Masonry Steel Wood | Noted | Y | N | N | N | Y, if possible | N | Date noted |

Table 3
CONFIGURATION ASPECTS

| PROCEDURE/ Source | Soft Story | Plan Irregularity | Vertical Irregularity and Variation in Stiffness | Excessive Openings | Aspect (Vertical or Horizontal) | Corner Building |
|---|---|---|---|---|---|---|
| CITY OF REDLANDS/ Mel Green & Assoc. (1986) | N | N | N | N | N | Y can be inferred from site location sketch |
| SAN FRANCISCO/ Frank Lew | Noted | Noted | Noted | N | N | N |
| ABAG/ J. Perkins et. al. (1986) | Y | Y | Y | Y | Y | N |
| STANFORD PROJECT/ JABEEC TR 81, Thurston et al. (1986) | Y | Y | Y | Noted | Y | N |
| LOW-RISE/ Wiggins and Taylor (1986) | Y | Y | Y | Y | Y | N |
| PALO ALTO/ F. Herman | N | N | N | N | N | N |
| OAKLAND/ Arnold, Eisner (1984) | Y | Y | Y | Y | N | N |

Table 3
(continued)

| PROCEDURE/ Source | Soft Story | Plan Irregularity | Vertical Irregularity and Variation in Stiffness | Excessive Openings | Aspect (Vertical or Horizontal) | Corner Building |
|---|---|---|---|---|---|---|
| MULTIHAZARD/ FEMA & Reitherman et al. (1984) | Y | Y | Y | Y large door width open side | N | N |
| NEW MADRID/ Allen & Hoshall (1983) | N | N | N | N | N | N |
| OSA HOSPITAL/ (1982) | Y | Y | Y | Y percent openings noted | Y | N |
| LOS ANGELES/ (1978-79) | Not specific percent openings | Y | Y | Y percent openings noted | N | N |
| UNIVERSITY OF CALIFORNIA/ McClure (1984) | Y | Y | Y | Y | Y | N/A |
| SANTA ROSA/ Myers (1981) | Y | Y | Y | Y | Y | Y |
| LONG BEACH/ Wiggins and Moran (1971) | N | Y | Y | Y | Y | N |
| NBS 61/ Culver et al. (1975) | Y, noted | N | Y, Noted | Y, noted | N | Street sides noted |

Table 4
SITE AND NON-STRUCTURAL ASPECTS

| PROCEDURE/ Source | SITE RELATED | | | | NON-STRUCTURAL | | |
|---|---|---|---|---|---|---|---|
| | Pounding | Neighboring Building Collapse | Soil Conditions | Potential for Other Geohazards | Infill Walls | Interior Partitions | Cornices, Overhang Parapets, Chimneys |
| CITY OF REDLANDS/ Mel Green & Assoc. (1986) | Noted abutting buildings | Noted abutting buildings | N | N | N | Noted type | Y cornice parapet chimney signs ornament |
| SAN FRANCISCO/ Frank Lew | N | N | N | N | N | N | Noted |
| ABAG/ J. Perkins et al. (1986) | N | N | Not explicit, used map overlay | Not explicit, used map overlay | N | N | N |
| STANFORD PROJECT/ JABEEC TR 81, Thurston et al. (1986) | Y | Y, noted | Y, noted | Y | Y | Y | Y |
| LOW-RISE/ Wiggins and Taylor (1986) | N | Y Neighboring overhang collapse | Y | N | Y | Y | Y |
| PALO ALTO/ F. Herman | N | N | N | N | N | N | N |

Table 4
(continued)

| PROCEDURE/ Source | SITE RELATED | | | | NON-STRUCTURAL | | |
|---|---|---|---|---|---|---|---|
| | Pounding | Neighboring Building Collapse | Soil Conditions | Potential for Other Geohazards | Infill Walls | Interior Partitions | Cornices, Overhang Parapets, Chimneys |
| OAKLAND/ Arnold, Eisner (1980, 1984) | N | N | N | N | Noted | N | Noted |
| MULTIHAZARD/ FEMA & Reitherman et al. (1984) | N | N | Y Soft or hard | Landslide liquefaction Settlement Surface faulting | Y noted | N | Braced or unbraced or not present |
| NEW MADRID/ Allen & Hoshall (1983) | N | N | Y | Liquefaction | N | N | Y |
| OSA HOSPITAL/ (1982) | Noted distance to nearest building | Noted distance to nearest building | N | Liquefaction Landslide Alquist-Priolo seismic zone | N | Y noted URM partitions | N |
| LOS ANGELES/ (1978-79) | N | N | N | N | N | Y | Y, also from previous parapet program |
| UNIVERSITY OF CALIFORNIA/ McClure (1984) | Not a problem | N | N | Y Surface faulting in a few locations | N | Y | Y, noted but not significant in ranking |

Table 4
(continued)

| PROCEDURE/ Source | SITE RELATED | | | | NON-STRUCTURAL | | |
|---|---|---|---|---|---|---|---|
| | Pounding | Neighboring Building Collapse | Soil Conditions | Potential for Other Geohazards | Infill Walls | Interior Partitions | Cornices, Overhang Parapets, Chimneys |
| SANTA ROSA/ Myers (1981) | Y | N | Not explicit, all on alluvial fill | Not explicit, no potential for liquefaction or surface faulting | Y | Y | Y |
| LONG BEACH/ Wiggins and Moran (1971) | Y | Y | Y | N | Y | Y | Y |
| NBS 61/ Culver et al. (1975) | Y, noted | Proximity to adjacent buildings noted, separation joints noted | Proximity to adjacent buildings noted | Y Fault rupture liquefaction (implicit fault location noted) | Y, noted and rated | Y, noted and rated | Y, noted and rated |

Table 5
PERSONNEL ASPECTS

| PROCEDURE/ Source | Survey personnel Approximate person-hours per building | Local Building Officials | Professional Engineers | Registered Architects | Building Owners | Emergency Managers | Interested Citizens |
|---|---|---|---|---|---|---|---|
| CITY OF REDLANDS/ Mel Green & Assoc. (1986) | Not available | Y | Y | Y | N | N | N |
| SAN FRANCISCO/ Frank Lew | 15 min per building | Y | Y | Y | N | N | N |
| ABAG/ J. Perkins | 5 min per building, Very little information noted | Y | Y | Y | Y | Y | N |
| STANFORD PROJECT/ JABEEC TR 81, Thurston et al. (1986) | Experienced structural engineer | Y | Y | Y | N | N | N |
| LOW-RISE/ Wiggins and Taylor (1986) | | Y | Y | Y | N | N | N |
| PALO ALTO/ F. Herman | 15 min per building | Y | Y | Y | Y | Y | N |

Table 5
(continued)

| PROCEDURE/ Source | Survey personnel Approximate person-hours per building | Local Building Officials | Professional Engineers | Registered Architects | Building Owners | Emergency Managers | Interested Citizens |
|---|---|---|---|---|---|---|---|
| OAKLAND/ Arnold, Eisner (1980, 1984) | 20 min per building | Y | Y | Y | N | N | N |
| MULTIHAZARD/ FEMA & Reitherman et al. (1984) | 1 hour to 3 days per building | Y | Y | Y | N | Y | N |
| NEW MADRID/ Allen & Hoshall (1983) | | N | Y | N | N | N | N |
| OSA HOSPITAL/ (1982) | 1-2 days per building | N | Y | Y | N | N | N |
| LOS ANGELES (1978-79) | 40 min per building | Y | Y | Y | N | Y | N |
| UNIVERSITY OF CALIFORNIA/ McClure (1984) | 20 min per building | N | Y | N | N | N | N |
| SANTA ROSA/ Myers (1981) | 1/2 day ($500) per building | Y | Y | Y | N | N | N |
| LONG BEACH/ Wiggins and Moran (1971) | Professional engineer | N | Y | N | N | N | N |

Table 5
(continued)

| PROCEDURE/ Source | Survey personnel Approximate person-hours per building | Local Building Officials | Professional Engineers | Registered Architects | Building Owners | Emergency Managers | Interested Citizens |
|---|---|---|---|---|---|---|---|
| NBS 61/ Culver et al. (1975) | 1 hour per building | Y | Y | Y | N | N | N |

# 5

# RECOMMENDED RAPID VISUAL
# SCREENING PROCEDURE

This section presents and discusses the elements of a recommended RSP, based on the results of the survey discussed above.

## 5.1 Elements of the Recommended RSP

In response to the conclusions (Section 4.7) reached from the survey of RSPs, an RSP employing the following elements is recommended:

- The Effective Peak Acceleration (EPA) values contained in the National Earthquake Hazards Reduction Program (NEHRP) Recommended Provisions for the Development of Seismic Regulations for New Buildings (BSSC, 1985), defined by Map Area, as an explicit measure of the ground motion.

- The building types contained in ATC-14 (i.e., wood frame, 5 steel types, 3 reinforced concrete, 2 pre-cast, 2 reinforced masonry, and 1 unreinforced masonry types).

- A systematic, simple structural hazard analysis scheme, based on a non-arbitrary measure of building performance for the specific building given the occurrence of the EPA. This scheme consists of a Basic Structural Hazard score, modified by penalties and bonuses to account for perceived deficiencies or strengths because of such factors as design level (inferred from age), condition, and configuration. The scheme involves only simple arithmetic, the score and penalties being added, to arrive at a final Structural Score S (A

high score corresponds to a low structural hazard, or is "good," and vice-versa.) The resulting S will relate back to the physical performance of the building, in terms of damage. (The basis for S is discussed further below).

- A simple clipboard data collection form, with space for:

  - a photograph of the building

  - a field sketch of the building

  - data from pre-field visit information (e.g., a summary from the Assessor's or other files, giving address, age, value, or owner's name, perhaps printed on a peel-off label that can be affixed directly to the data collection form)

  - a checklist of items (so that significant items are not omitted), with almost all input to be noted by circling of the appropriate item (so that standard notation is employed)

  - the simple calculation for S

This form and process is to be accompanied by a handbook (ATC-21) explaining its use and providing

- information on how to determine which of the building types is most appropriate for the particular building being surveyed

- explanations and guidance as to the recognition of various significant factors, such as pounding, poor configuration, or soft stories

- a summary sheet of basic information, for quick reference in the field

## 5.2 Basis for Structural Hazard Scores

It has been emphasized in the above that the Structural Hazard score should be rationally based and physically meaningful. It is recommended that it should be *a measure of the probability of major seismic damage to the building*. Major damage is taken to be direct physical damage being 60% or greater of the building value. (Note: definitions of building value, and related terms are similar to those in report ATC-13, (ATC, 1985), "*Earthquake Damage Evaluation Data for California*").

Sixty percent as heavy damage is selected because (i) it is the lower end of the Major Damage State in ATC-13, (ii) if 60 percent of a building's value is damaged, experience has shown that demolition rather than repair often ensues, and (iii) if 60 percent damage is selected, then most buildings likely to collapse will be included in this category, so that life-safety-related hazardous buildings (due to shaking) are probably all captured.

By employing NEHRP EPA values as the measure of ground motion, ATC-13 relations can be used to determine the probability of occurrence of 60 percent or greater damage, given that input ground motion (see Appendix B for details). The determination of the Basic Structural Hazard score then is:

Basic Structural Hazard score =
$$-\log (\text{probability of damage} >= 60\%) \quad (1)$$

If the probability of the damage exceeding 60%, given the NEHRP EPA value for the building's site, is, for example, .001, then the Basic Structural Hazard score is 3. If the probability is .01, then it is 2, and so on.

- Although quite simple, the Basic Structural Hazard score is thus intuitively satisfying. A relatively "safe" building would have values of 3 to 5 in California, whereas the identical building would score approximately 7 to 10 in NEHRP Map Area 3, corresponding to New England or the South Carolina regions, as it is likely to experience less severe ground motion. Note, however, that because many buildings in less seismic areas are not designed for earthquake on the same basis as in California, when this is taken into account the resulting score is more consistent for the same building type in different NEHRP map areas (e.g., in the range of 3 to 5). Values of the Basic Structural Hazard score are provided in Table B1, Appendix B.

- The Basic Structural Hazard score can be easily and directly related back to the probability of major physical damage (i.e., damage exceeding 60 percent of building value).

- The Basic Structural Hazard score will likely prove of value in community cost-benefit decision making because it can be directly related to physical damage.

- The ability to relate Basic Structural Hazard score to physical damage has the further virtue of providing a rational analytical basis for quantifying structural penalties for factors such as age, and configuration. If the impact of these factors on the likelihood (or probability) of major damage can be quantified, then the logarithm of this quantity is the modifier. Although lack of data and the present state of the art may preclude general quantification of the effect of a factor such as "soft story" at present, as new data emerge on the effect of this factor, its quantification can be directly related to a penalty on the Basic Structural Hazard score. In the interim, discussion and expert opinion/elicitation regarding the effect of this factor can take place within the framework of

trying to quantify the impact of this factor on the probability of major damage.

### 5.3 Data Collection Form

This section discusses the layout and use of data collection form, which is shown in Figure 1. The form would be carried in the field in a binder or clipboard.

### Basic Information

Space is provided in the upper right of the form for basic information, much of which might be collated and printed out prior to the field visit. Information desired includes address, zip code (although often lacking from the studies reviewed, this is a useful item), the date of the survey, and identity of the surveyor. Additional useful information about the building such as age, construction type, soil type, and value is also desirable. Preferably, such information should either be computer-printed out directly onto the form, or onto a peel-off label applied by the field surveyor. This information would be quickly entered or affixed as the first item upon coming to the building.

### Photograph

A general photo of the building should be taken, showing two sides of the building, if possible. (This would preferably be an "instant" type photo, to avoid the task of later collating photos with forms.)

### Sketch

The surveyor would then sketch the building (plan and elevation, or oblique view) indicating dimensions, facade and structural materials, and observed special features such as cracks, lack of seismic separation between buildings, roof tanks, cornices, and other features. This sketch is important, as it requires the surveyor to carefully observe the building.

### Building Information

Following this, the surveyor would fill in additional basic information specific to the building such as number of stories; an estimate of the building age (e.g., 1930's or late 1960's), the occupancy (e.g., residential, office, retail, wholesale/warehouse, light industrial, heavy industrial, public assembly such as auditoria or theaters, governmental); and an estimate of the number of persons typically in the building under normal occupancy. For example, for a residence, this would be the number of persons living there (not the daytime population); for an office this would be the daytime population; for a theater this would be the seating capacity.

### Basic Structural Hazard Score

Next, based on observation, the surveyor would make a determination of the primary structural material (wood, steel, concrete, pre-cast, reinforced masonry or unreinforced masonry) and circle the appropriate Basic Structural Hazard score. The basis for determination of Basic Structural Hazard scores are given in Appendix B. The building types follow the building category scheme of ATC-14 (ATC, 1987).

*Wood*

W = wood (low-rise (LR) only, W1 and W2 treated together)

*Steel*

S1 = moment resisting frame
S2 = steel frame with steel bracing
S3 = light metal (LR only)
S4 = steel frame with concrete shear walls
S5 = steel frame with unreinforced masonry infill walls

### Concrete

C1 = moment resisting frame
C2 = shear wall
C3 = concrete frame with unreinforced masonry infill walls

### Precast

PC1 = tilt-up (LR only)
PC2 = precast concrete frames

### Reinforced Masonry

RM = reinforced masonry buildings of all types, differentiated only by height

### Unreinforced Masonry

URM = unreinforced masonry bearing wall (LR and mid-rise (MR) only).

Any specific jurisdiction corresponds to one NEHRP Map Area, and the form used in the field for that jurisdiction would have Structural Scores corresponding only to that Map Area/jurisdiction. All NEHRP Map Areas and corresponding Structural Scores would be furnished in the Handbook.

## Confidence

If in doubt as to which category is most appropriate for a particular building, the surveyor should record the possible categories and mark them with an asterisk (*) to indicate the subjective evaluation.

If the surveyor cannot narrow the estimate to two alternates, DNK = Do Not Know should be indicated, signifying that the basic structural material or system cannot be identified from the street. DNK would also apply for a building of mixed construction, where no one category predominates. DNK constitutes a default, indicating that the building and drawings should be reviewed in detail.

## Modifiers

Negative modifiers corresponding generally to deficiencies such as poor configuration, pounding, and potential for a neighboring building collapsing onto this building (this penalty would depend on the Basic Structural Hazard score for the neighboring building being sufficiently low as to indicate a potential for collapse, and the height and proximity of the neighboring building being such as to indicate that collapse might affect the subject building).

## Soil Profile

Modifiers assigned for adverse soil conditions when the soil profile can be identified with some confidence. Soil profiles have been defined according to the NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings (BSSC, 1985):

SL1: Rock or stiff soils less than 200 feet deep overlying rock

SL2: Deep, cohesionless soil or stiff clay conditions exceeding 200 feet depth

SL3: Soft- to medium-stiff clays and sands, exceeding 30 feet in thickness

## Structural Score S

Lastly, the Structural Score S is computed by simple addition of the modifiers to the Basic Structural Hazard score. The final Structural Score S is recorded.

## 5.4 Use of the Results

For any building, the final Structural Score S will typically be a number between 0 and 5 or more, depending on NEHRP Map Area. All buildings surveyed can thus be ranked according to S, and a decision made as to a "cut-off" S. Buildings that score below the cut-

off would be subjected to more detailed review. Scoring above the cut-off does not signify a "safe" building, but instead indicates that for the particular community the building is assumed sufficiently safe, and no further review is required.

An appropriate value for the cut-off S is a complex decision, involving financial and ethical questions. Appendix C provides recommendations for a cut-off S. This recommendation should be reviewed and, if necessary, modified by a jurisdiction, as the decision has cost implications. (That is, a relatively high cut-off involves detailed review of a large number of buildings, with increased costs and presumably eventual increased seismic safety, assuming buildings determined to be unsafe are cited and abated. A lower cut-off has lower costs for building review, but may involve lower resulting seismic safety.)

## ATC-21/ (NEHRP Map Areas 5,6,7 High)
### Rapid Visual Screening of Seismically Hazardous Buildings

Address _____
_____ Zip_____
Other Identifiers_____
No. Stories _____ Year Built _____
Inspector _____ Date _____
Total Floor Area (sq. ft)_____
Building Name_____
Use_____

(Peel-off label)

Scale:

INSTANT PHOTO

| OCCUPANCY | | 
|---|---|
| Residential | No. Persons |
| Commercial | 0-10 |
| Office | 11-100 |
| Industrial | 100+ |
| Pub. Assem. | |
| School | |
| Govt. Bldg. | |
| Emer. Serv. | |
| Historic Bldg. | |

Non Structural Falling Hazard ☐

**DATA CONFIDENCE**

☆ = Estimated, Subjective, or Unreliable Data

DNK = Do Not Know

### STRUCTURAL SCORES AND MODIFIERS

| BUILDING TYPE | W | S1 (MRF) | S2 (BR) | S3 (LM) | S4 (RC SW) | C1 (MRF) | C2 (SW) | C3/S5 (URM INF) | PC1 (TU) | PC2 | RM | URM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Basic Score | 4.5 | 4.5 | 3.0 | 5.5 | 3.5 | 2.0 | 3.0 | 1.5 | 2.0 | 1.5 | 3.0 | 1.0 |
| High Rise | N/A | -2.0 | -1.0 | N/A | -1.0 | -1.0 | -1.0 | -0.5 | N/A | -0.5 | -1.0 | -0.5 |
| Poor Condition | -0.5 | -0.5 | -0.5 | -0.5 | -0.5 | -0.5 | -0.5 | -0.5 | -0.5 | -0.5 | -0.5 | -0.5 |
| Vert. Irregularity | -0.5 | -0.5 | -0.5 | -0.5 | -0.5 | -1.0 | -0.5 | -0.5 | -1.0 | -1.0 | -0.5 | -0.5 |
| Soft Story | -1.0 | -2.5 | -2.0 | -1.0 | -2.0 | -2.0 | -2.0 | -1.0 | -1.0 | -2.0 | -2.0 | -1.0 |
| Torsion | -1.0 | -2.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 | -1.0 |
| Plan Irregularity | -1.0 | -0.5 | -0.5 | -0.5 | -0.5 | -0.5 | -0.5 | -0.5 | -1.0 | -1.0 | -1.0 | -1.0 |
| Pounding | N/A | -0.5 | -0.5 | N/A | -0.5 | -0.5 | N/A | N/A | N/A | -0.5 | N/A | N/A |
| Large Heavy Cladding | N/A | -2.0 | N/A | N/A | N/A | -1.0 | N/A | N/A | N/A | -1.0 | N/A | N/A |
| Short Columns | N/A | N/A | N/A | N/A | N/A | -1.0 | -1.0 | -1.0 | N/A | -1.0 | N/A | N/A |
| Post Benchmark Year | +2.0 | +2.0 | +2.0 | +2.0 | +2.0 | +2.0 | +2.0 | N/A | +2.0 | +2.0 | +2.0 | N/A |
| SL2 | -0.3 | -0.3 | -0.3 | -0.3 | -0.3 | -0.3 | -0.3 | -0.3 | -0.3 | -0.3 | -0.3 | -0.3 |
| SL3 | -0.6 | -0.6 | -0.6 | -0.6 | -0.6 | -0.6 | -0.6 | -0.6 | -0.6 | -0.6 | -0.6 | -0.6 |
| SL3 & 8 to 20 stories | N/A | -0.8 | -0.8 | N/A | -0.8 | -0.8 | -0.8 | -0.8 | N/A | -0.8 | -0.8 | -0.8 |
| FINAL SCORE | | | | | | | | | | | | |

**COMMENTS**

ATCSFM
53009.01

Figure 1. Data Collection Form

Detailed Evaluation Required?

YES   NO